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Earth Studies using L-band Synthetic Aperture Radar

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To the Reviewer of this Package:

- **The following text slides will be supplemented by color images taken from published literature. This is a review talk, so there should be no concern about technology transfer or ITAR violations.**

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Why L-band?

- **Physics of scattering**

Strengths of L-band SAR Observations

- **Show that L-band has more stable temporal properties**
- **Show that L-band penetrates vegetation**
- **Show that L-band penetrates dry soils**
- **Use published data to do so**



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Timeline of Civilian L-band SAR Development

- **Make a timeline showing known SAR's using L-band in history from published records.**



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Early L-band Radars and Missions

- **SEASAT**
- **SIR-A**
- **SIR-B**
- **AIRSAR**



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Early L-band Radars and Missions Science Results

- **Oceans**
- **Land cover**
- **Penetration**
- **Archaeology**



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Polarimetric L-band Radars and Missions

- **AIRSAR**
- **SIR-C**

Polarimetric L-band Radar Science Results

- **Land cover classification**
- **Soil moisture results**
- **Snow depth and coverage results**



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Interferometric L-band Radars and Missions

- **TOPSAR**
- **SIR-C**
- **JERS-1**

Interferometric L-band Radar Science Results

- **TOPSAR L-C comparison of topography**
- **SIRC L-band DEM**
- **Hawaii deformation using SIR-C**
- **Kobe and Northridge using JERS**
- **Amazon mosaic and change signatures**

The Place of JERS-1 in History

- **JERS is the first long-term Earth observing system at L-band**
- **JERS showed that sustaining measurements over six years creates a valuable L-band database for**
 - **Crustal Deformation Studies**
 - **Land cover change**
- **Experience with JERS shows us how to design future L-band SARs for science applications**

Future Trends L-band SAR

- **Finer Resolution**
 - **To recover optical quality imagery over targeted areas**
- **Expanded role of interferometric systems for science and commercial applications**
 - **Fine resolution topography**
 - **Land-use classification and management**
 - **Disaster management and mitigation**
- **Polarization and Frequency Diversity**
 - **To recover surface height and canopy height/class**

ECHO-Elsie Concept

- **Place ECHO-Elsie summary chart here**

ECHO-Elsie Status

- **Proposal was *not* selected because it was not ranked as highly as other proposals**
- **Proposal was evaluated by NASA to be “selectable”, and the science and technical plan was highly regarded.**
- **Many of the concepts proposed for ECHO-Elsie have made their way into the science requirements listed in the LightSAR Announcement of Opportunity**

Expected characteristics of LightSAR

Based on Announcement of Opportunity LightSAR:

- **Must primarily focus on crustal deformation and ice motion mapping using L-band repeat-pass interferometry**
- **Will secondarily study biomass and canopy properties using L-band full polarization observations.**
- **Will have funding limited to about \$120M from NASA, so additional funds needed must be provided by proposal partners**
- **May have high resolution modes at L-band or X-band to satisfy commercial markets, but these are not required**
- **Is a dynamic approach to a radar mission**



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Expected Characteristics of ALOS

- **Place characteristics from Japanese ALOS briefing package here**

Earth Observing System Follow-on Plans

- **NASA plans to fly *science* missions that use SAR instruments:**
 - Sustaining deformation measurements on the decadal scale beyond LightSAR
 - Land cover and biomass decadal change
 - Soil moisture and freeze-thaw monitoring
- **Some of these instruments will use L-band as at least one of the bands**
- **NASA and NASDA may be able to find common ground in future L-band observing campaigns**

Conclusions

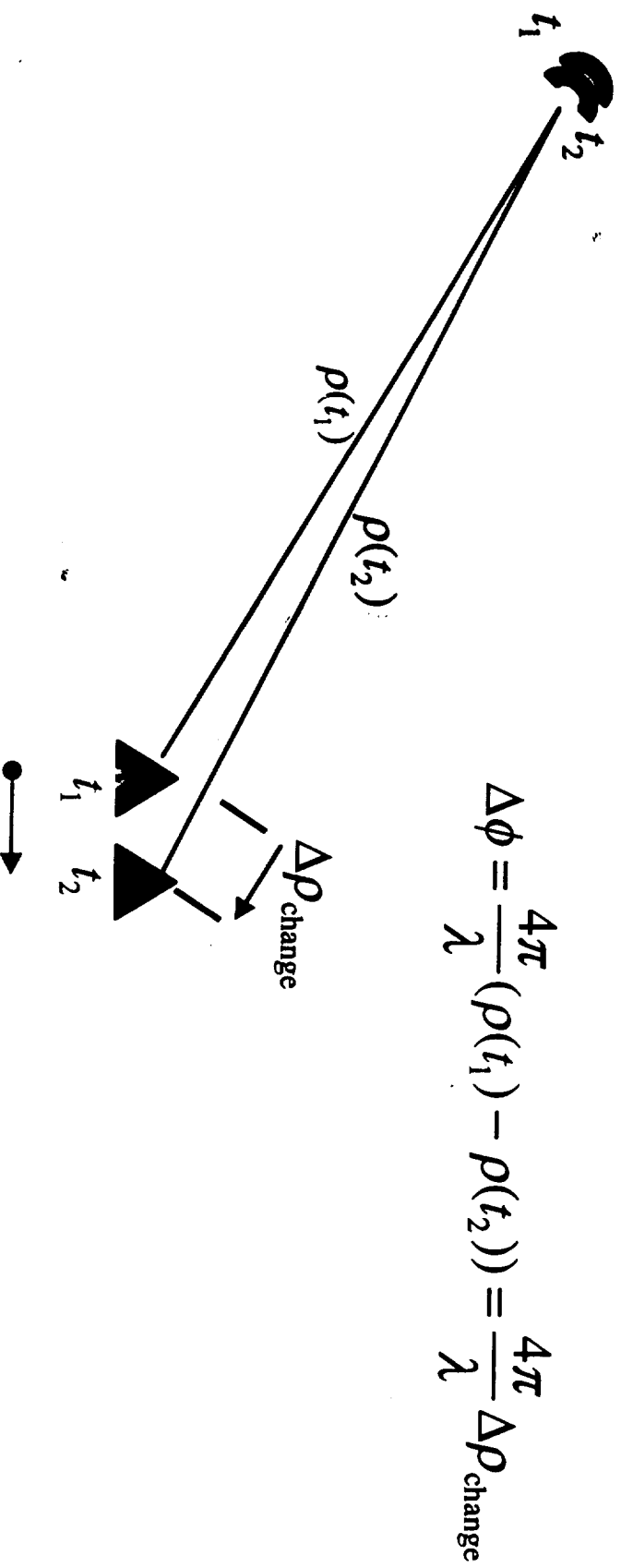
- **L-band SAR has played an important role in studies of the Earth by revealing the nature of the larger-scale (decimeter) surface features**
- **JERS-1, by supplying multi-seasonal coverage of the much of the Earth, has demonstrated the importance of**
- **Future L-band SARs such as ALOS and LightSAR will pave the way for science missions that use SAR instruments**
- **As technology develops to enable lower cost SAR instruments, missions will evolve to each have a unique science focus**
- **International coordination of multi-parameter constellations and campaigns will maximize science return**

Digital Technologies for Topography Generation in the Next Decade

- **Optical Stereo Mappers**
 - **SPOT (France), ALOS (Japan), EOS (USA), Commercial**
 - **Traditional but so far unable to deliver global products**
- **Spaceborne Laser Altimeters**
 - **IceSAT, VCL (USA)**
 - **New technology delivering profiles of canopy height**
 - **Lack of coverage prevents global mapping**
- **Radar Interferometry**
 - **SRTM (USA)**
 - **New technology expected to deliver global products**
- **Repeat-pass Radar**
 - **RadarSAT (Can), ALOS (Japan), EnvisAT(ESA), LightSAR (USA)**

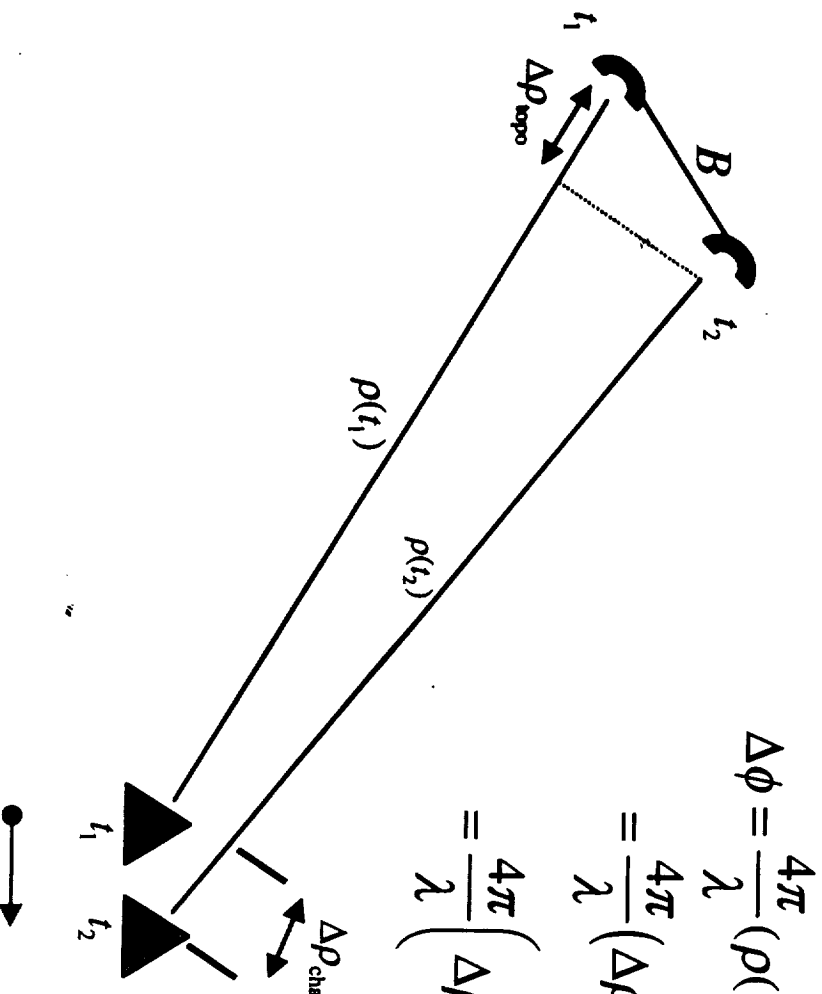
Differential Interferometry

When two observations are made from the same location in space but at different times, the interferometric phase is proportional to any change in the range of a surface feature directly.

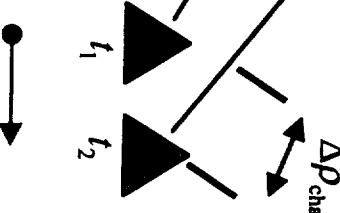


Differential Interferometry and Topography

Generally two observations are made from different locations in space and at different times, so the interferometric phase is proportional to topography and topographic change.



$$\begin{aligned}
 \Delta\phi &= \frac{4\pi}{\lambda}(\rho(t_1) - \rho(t_2)) = \frac{4\pi}{\lambda}(\Delta\rho_{\text{change}} - \Delta\rho_{\text{topo}}) \\
 &= \frac{4\pi}{\lambda}(\Delta\rho_{\text{change}} - B\sin(\theta - \alpha)) \\
 &= \frac{4\pi}{\lambda} \left(\Delta\rho_{\text{change}} - B\cos(\theta_0 - \alpha) - \frac{z}{\rho_0 \sin\theta_0} \right)
 \end{aligned}$$



If topography is known, then second term can be eliminated to reveal surface change

SRTM Topography for Surface Change Applications

- If one uses SRTM data to remove topography in an interferogram to reveal surface change, then its height noise will contribute a phase noise component

$$\sigma_{\phi} = \frac{4\pi}{\lambda} \frac{B_{\perp}}{\rho_0 \sin \theta_0} \sigma_z \Rightarrow \sigma_{\Delta \rho_{\text{change}}} = \frac{B_{\perp}}{\rho_0 \sin \theta_0} \sigma_z$$

- What is the baseline below which the 10 m SRTM height noise contributes less than 3mm of displacement noise?

$$B_{\perp} < \frac{\sigma_{\Delta \rho_{\text{change}}}}{\sigma_z} \rho_0 \sin \theta_0 \approx 130\text{m}$$

For typical polar-orbiting SARs